DESIGN AND IMPLEMENTATION OF INGASB INFRARED THERMOMETER FOR DIAGNOSING THE HEALTH CONDITION IN VIVO USING IOT INFRASTRUCTURE

A SYNOPSIS

Submitted by

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in partial fulfillment for the award of the degree

of

DOCTOR OF PHILOSOPHY

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

SCHOOL OF ELECTRONICS AND ELECTRICAL TECHNOLOGY

KALASALINGAM ACADEMY OF RESEARCH AND EDUCATION

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TAMILNADU, INDIA

JULY 2022

1. INTRODUCTION

1.1 Thermometer

An instrument that measures temperature is a thermometer. Celsius, Fahrenheit, and Kelvin are the three most popular temperature measuring units. Body temperature is an essential indicator of a patient's clinical evaluation, medical decisions, research and management of children in emergency observation units. While investigating allergiesand anaphylactic symptoms, temperature has been considered as the prime factor of importance. The typical normal body temperature is 98.6 ºF (37 °C). Well-known methods for measuring the body temperature of humans includeaxillary measurement, oral measurement, and rectal measurement.

1.2 Types of Thermometer

There are four different types of temperature measurement devices, each with its own operating principle, such as Thermocouples, Thermistors, Resistance TemperatureDetector (RTD), Radiative (Infrared).

(i) Thermocouple

There are many different ways to measure temperature, but thermocouples, which use thermoelectric devices, are the most widely used. By utilizing the seebeck Effect, thermocouples measure temperature by measuring the difference in voltage between the sensor tip and the wire's end, which is determined by a material's seebeck co- efficient.

(ii) Thermistors

Temperature-sensitive resistors, such as thermistors, have the primary function of changing electrical resistance dramatically, predictably, and precisely in response to a change in body temperature. Negative coefficients indicate that a material's resistance decreases as the temperature rises. Carbon, silicon, and germanium all have negative temperature coefficients of resistance, which makes them ideal for use in semiconductors.

(iii) RTD (Resistance Temperature Detector)

An RTD (Resistance Temperature Detector) is a type of sensor whose resistance changes in response to changes in its temperature. The resistance increases as the sensor's temperature rises. Resistance vs. temperature is a well-known and repeatable connection. An

RTD operates on a simple principle: as the temperature of a metal increases, the resistance to the flow of electricity increases proportionately. The sensorconducts electricity, and the resistance element is used to determine the resistance of the current.

(iv) Rectal Probes

A rectal thermometer is a thermometer that is inserted in the rectum to check the body's internal temperature. Rectal temperature is a method for measuring a child's temperature. Caregivers may wish to take rectal temperatures of children younger than5 years of age.

Invasive methods have been the origin of non-invasive measurement methods like Thermocouple electrodes, rectal probes, Resistance Temperature Detector (RTD) and fiber optic probes. In general, rectal probes are normally used for temperature analysis,and they have been verified to be precise and invaluable in this esteem. Infrared radiation thermometers do not require invasive contact with the object being measured,they overcome many of the limitations of thermocouples, thermistors, RTD and rectal probs.

1.3 Infrared Thermometer

Infrared Thermometer measure radiant energy radiated by the object andtransforms it into an electrical signal using sensing components. Infrared thermometeris made up of two parts: an infrared (IR) lens and a detector. The detector turns the IR radiation into an electrical signal, which can then be represented in units of temperature. More sensitive detector technologies are necessary to improve on the current generationof radiation thermometers. Infrared thermometers use photosensitive sensors, such as semiconductor photodiodes, to determine the temperature. Modern infrared temperature measuring devices come in a variety of configurations, including handheld,flexible, portable, and wall-mounted. Infrared sensors are classified in two categories, photon infrared sensors and thermal or uncooled infrared sensors. The two approaches are quite different in their working principles and material properties.

(i)Photon Infrared Sensors

Photon infrared sensors utilize photon nature of the infrared radiations in their detection. Photoconductivity, photovoltaic, or photoemission are all methods for converting incident radiation into an electric signal. Where the free charge carrier generation is proportional to the interaction of incident photons with optically sensitivematerials like HgCdTe, InGaAs, Ge, PbSe, PbS, AlAs etc.

(ii)Thermal IR Sensor

A thermal IR sensor uses infrared energy as heat for detection and its sensitivity is independent of wavelengths. Therefore, it can detect objects in the near IR, mid IR, andfar IR bands. The non-contact detectors do not require cooling after exposure but have slow response times and low resolution. Infrared radiation (IR), also called thermal radiation, is a type of electromagnetic radiation with wavelengths between 780 nm and1 mm that are above red light. IR is broken up into three groups: IR-A (780 nm–1.4 m),IR-B (1.4–3 m), and IR-C, or far-IR (3 m–1 mm).

1.4 Types of Infrared Thermometers

(i) Infra-red Skin Thermometry

The temperature of the skin has been used to estimate the temperature of the body. Skin's infrared radiation can theoretically be utilized to determine its temperature. The skin possesses a high emissivity (reported to be around 0.98) on the other hand, skin temperature does not always correspond to core body temperature.

(ii) Tympanic Thermometry

IRT is a rapid detection method and the most commonly used IRTs measure the temperature of the tympanic and the forehead. The tympanic is close to the core temperature of the body and gives the most accurate representation of the bodytemperature.

(iii) Forehead Thermometry

Measurements can be taken on the forehead because the temporal artery brings core blood to temples. A forehead IRT is convenient and noninvasive, so any chance of mutual infection is minimized. Public locations, such as airports, schools, hospitals, and transit vehicles, used this sort of technology to screen the public during the COVID-19 situations. More sensitive detector technologies are necessary to improve on the current generation of radiation thermometers. Infrared thermometers make use of photosensitive sensors, such as semiconductor photodiodes, to determine the temperature. Temperature-dependent materials such as Si, Ge, and GaAs, HgTe, and HgCdTe are used to make photo diodes. Cui et al. [1] designed the resistance temperature detectors are used to measurethe core body temperature. Prior to the construction of any infrared sensors, it is necessary to take into consideration a number of parameters, like wavelength, frequency, photon energy level, and values are

mentioned as follows: 700 nm- 1mm, 430THz – 300GHz, 1.7ev – 1.24 meV respectively.

In this work, Table 1 refers the different temperature dependent material used in photodiodes. Konishi and Hirata [2] presents a micro finger with temperature sensing functionality. Moreover, thermocouples, which detect temperature based on the See beck effect, are designed for use as flexible temperature sensors. Wang et al. [3] made and analysed a high-precision Complementary Metal-Oxide- Semiconductor (CMOS) temperature sensor for the temperature range of (5 ^{o}C to 120 ^{o}C). A temperature range selection circuit is part of the thermistor linear circuit, whichis used to measure the temperature. Table 2, specifies the parameters of designing infrared thermometer, and various types of commercially available photo diodes. Because of its high thermal conductivity for infrared radiation, a TSFF5210 photodiode based on Indium Gallium Antimony (InGaSb) material was employed to measure the temperature of a human being in this work.

Table 1: Temperature Dependent Material

S.No.	Material	Wavelength	References
1.	HgTe colloidal quantum dots	2.6 µm	Ackerman, M. M., Chen, M., & Guyot-Sionnest, P. (2020).
2.	InGaAs	2.2 µm	Ackerman, M. M., Chen, M., & Guyot-Sionnest, P. (2020).
3.	InAs	3.3-3.4 µm	Dyakonova, N., Karandashev, S. A., Levinshtein, M. E., Matveev, B. A., & Remennyi, M. A. (2020).
4.	PbS NPs	0.9 – 1.7µm	Wang, C., Zhang, X., & Hu, W. (2020).
5.	Mn doped CdO	290 nm to 330 nm 820 nm to 860 nm.	Dugan, S., Koç M. M., & Coşkun, B. (2020).
6.	Lead Sulfide Quantum Dots (PbS NPs)	2600nm	Dong, Chen, et al. (2019).

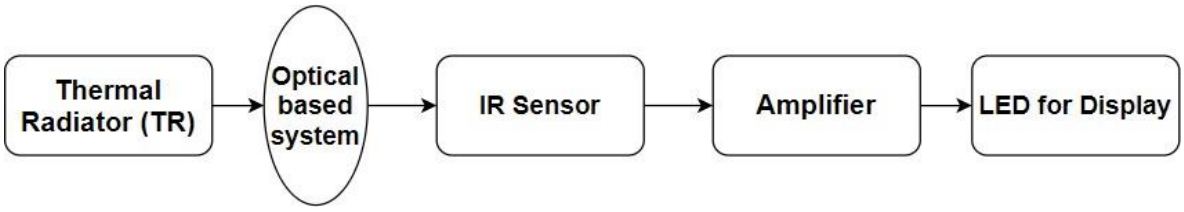


Figure 1: Flow of Infrared (IR) based Thermometer for Measuring Temperature

A significant element of infrared devices is that the surface temperature of an experiment can estimates without any contact with the target object. In this manner, this can be effectively estimating an objective temperature, which is a tedious tactic.The sensor design is illustrated in Figure 1. The distance between the infrared thermometer and the deliberate article is around 400 mm, as illustrated in Figure 2.

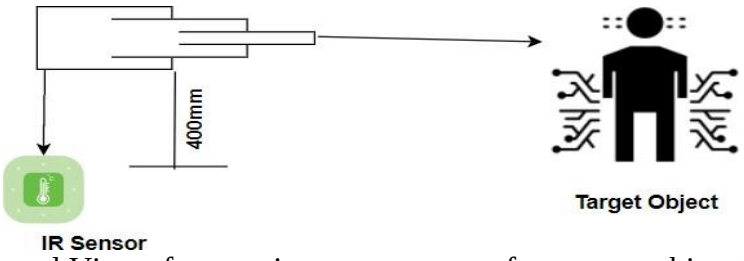


Figure 2: Structural View of measuring a temperature for a target object (Human Being)

Table 2: Comparison between Photodiodes

S.No	Types of Photodiodes	Ambient Temperature	Object Temperature.	Angle of Half Intensity ϕ	Good Spectral Matching	Peak wavelength
1.	TSFF5210	- 40 to + 85°C	- 40 to +100°C	± 10°	Si photodetectors	λp = 870 nm
2.	VSLY5850	- 40 to + 85	- 40 to + 100	± 3°	CMOS cameras	λp = 850 nm
3.	TSHG6410	- 40 to + 85	- 40 to + 100°C	± 18°	CMOS cameras	λp = 850 nm

The temperature of an in vivo is measured using an InGaSb infrared thermometer. Wireless sensor networks will receive temperature measurement data and forward it to the cloud for storage. An energy-efficient algorithm was used to send the recorded temperature data to the cloud via a wireless sensor network. Keeping this in mind, this work proposed an Energy Efficient Bio-Inspired Mimosa Pudica (EEBIMP) algorithm. EEBIMP for WVSN can reduce the time delay and avoidunnecessary energy consumption. EEBIMP algorithm has been compared with one of the most recent notable solutions, like GREENNESS, PSO (Particle Swarm Optimization), and Cuckoo Search algorithm. The results show that EEBIMP achieved 95% of energy efficiency when compared with other energy efficiency algorithms. The temperature of an in vivo is measured using an InGaSb infrared thermometer, and measured temperature data is transferred to the cloud using the EEBIMP algorithm. So, in this work, the rectal temperature is obtained by measuring the temperatures of cow using InGaSb infrared thermometer. By considering this aspect, the developed work

can be extended to livestock application in order to exhibit excellent and competitive performances, which will undoubtedly show better results in the near future.

2. LITERATURE REVIEW

Gu et al. [4] states that flexible and wearable devices based on skin-friendly soft elastic materials can be snugly attached to the surface of human skin, In order to help the patient maintain a healthy lifestyle, vital health data such as wrist pulse, body temperature, and blood glucose can be retrieved and examined. Chaglla et al. [5] measure an entity's infrared (IR) radiation and use it todetermine the thermostat from a distance. The thermopile pressure sensor uses light andnonlinear effects and is made up of tiny temperature sensors on a microchip. An ear-based system has been used for continuous measurement of ear temperature and to validate the output ofthis device by comparing it with other commercial ear thermometers. Since it has been demonstrated that tympanic temperature changes when a person is exposed to cold, Brinnel and Cabanac [6] discuss the precision of this measurement of core temperature. This research was conducted to determine whether the skin's temperature could have an impact on the eardrum's temperature. Mogensen et al. [7] measured rectal temperature in children as the gold standard, but ear or forehead measures are less traumatic and faster. The quality of non-invasive devices has improved but concerns remain whether they are reliable enough to substitute rectal thermometers. Zhou et al. [8] described Si and In0.47Ga0.53As (hereafter referred to as standard InGaAs) photodiodes are currently widely used in radiation thermometry. For example, by increasing the Indium (In) composition, extended InGaAs photodiodes detecting up to 2.6μm are commercially available. Thisenables commercial thermometers to detect temperatures down to 50 ^{o}C Since an InAsphotodiode can easily detect radiation at 3.43 μm. Yoon et al. [9] discussed about Germanium (Ge) and indium gallium arsenide (InGaAs) photodiodes are frequently used as photodetector technology in such equipment due to their excellent photo response at this application wavelength. Due to its stronger shunt resistance, lower noise, and less sensitivity to the ambient temperature, the InGaAs photodiode has recently surpassed the Ge photodiode as the industry standard detector technology for 1.6 m radiation thermometry. Chen et al. [10] depicted the Temperature monitoring is one of the most effective wireless sensor network applications. It becomes much more significant with the quick rise of cloud computing, because cloud servers have to function in acceptable temperature range for purpose of achieving near-optimal capability and security.

Sarmah et al. [11] developed a new, experimental method of employing a localization algorithm for a temperature monitoring system that has been shown to be effective. Mohan Kumar et al. [12] built a prototype of an embedded wireless sensor network based on easy-to-use Arduino microcontroller board and Xbee module. Boonsawat et al. [13] proposed for combining clustering and routing techniques to increase network lifetime and network usage. While designing the clustering algorithm a routing technique is needed to reach the minimum time for data to reach its destination with less battery utilization. Igiri et al. [14] compared the bio-inspired algorithms in several fields based on various natural occurrences such as Bat Algorithm (BA), Firefly algorithm (FA), Artificial Bee Colony (ABC), Particle Swarm Optimization (PSO) algorithm, and Differential Evolution (DE).

Murugeswari and murugan [15] proposed a frame structure model of a Versatile Synchronization Guard Band Protocol (VSGP) for QOS and Energy efficiency, which introduces a guard band (GB) in each time slot, for reducing the interference of the transmitting signal. Iwasaki et al. [16] discussed various devices designed to acquire data on animal temperatures invasively. Intra-vaginal radio transmitters' data loggers, reticular boluses, and rectal probes are some of the approaches used. Recently, automatic monitoring systems have been used to evaluate the subcutis, vagina, and rumen, but these methods have not yet been standardized. It has not been properly examined whether there are significant differences across measurement sites and the optimal places to monitor core body temperature. To address these challenges, Iwasaki et al. [17] constructed implantable wireless thermometers and tested them for long-term temperature monitoring at a variety of sites before concluding that endoceliac sites and the tail base are excellent options for bovine temperature monitoring. In these cases, implantable sensors are harmful to animals and are problematic as they induce infection in the cow herd. There are some problems with keeping an eye on a cow's temperature, but there are non-invasive infrared thermometers that can do a lot of useful things.

Nogami et al. [18] explained drinking water causes the rumen temperature to drop rapidly, making this site ineffective for measuring the body's core temperature. Recently, Giro et al. [19] concluded that among the methods used for determining the body temperature, such as clinical thermometry's golden rule, infrared thermometry (two distinct regions), and RFID technology, infrared thermometry is reported to have the best results.

Bobić et al. [20] measured the heat radiation from the outside of a body using infrared thermometry, which measures the internal body temperature of dairy cattle in the pasture. Its effectiveness must be evaluated in relation to the clinical thermometry system. Recently, According to the above-mentioned studies, non-invasive infrared procedures are not detrimental to animals and are safer. So far, the reports have employed commercially accessible infrared sensors to assess the temperature of cattle. This has paved the way to developing a non-invasive infrared thermometer for the diagnosing the health condition of livestock.

3. OBJECTIVES OF THE WORK

The main objectives of this research work are:

1. To design and develop an Infrared thermometer for measuring temperature In-vivo.
2. To implement an Energy Efficient Algorithm for effective transmission of temperature data in to the wireless sensor network.
3. To measure the temperature of cow in real time implementation with the proposed Infrared thermometer.

4. RESEARCH PROBLEM

- Invasive temperature measurement harm the living things
- Energy efficient algorithm is required to transfer the data
- Rectal temperature measurements harm the cow, when affected by diseases.

5. CONTRIBUTIONS

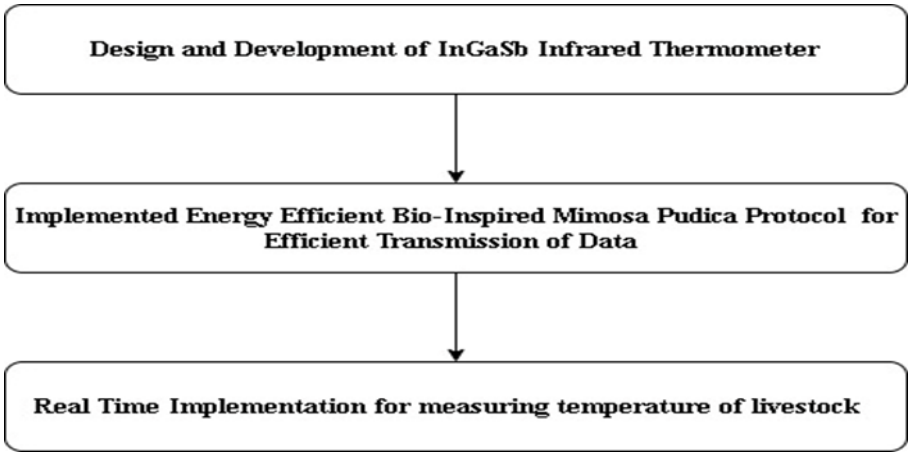

Design and Development of InGaSb Infrared Thermometer
Implemented Energy Efficient Bio-Inspired Mimosa Pudica Protocol for Efficient Transmission of Data
Real Time Implementation for measuring temperature of livestock

Figure 3: Over All Work Flow

Figure.3. illustrate the overall work flow, an InGaSb infrared thermometer used to measure the temperature of in vivo. Wireless sensor networks will receive temperature measurement data and forward it to the cloud for storage. An energy-efficient algorithm was used to send the recorded temperature data to the cloud via a wireless sensor network.This work proposed an Energy Efficient Bio-Inspired Mimosa Pudica (EEBIMP) algorithm. EEBIMP for WVSN can reduce the time delay and avoid unnecessary energy consumption. EEBIMP algorithm has been compared with one of the most recent notable solutions, like GREENNESS, PSO (Particle Swarm Optimization), and Cuckoo Search algorithm. The results show that EEBIMP achieved 95% of energy efficiency when compared with other energy efficiency algorithms. The temperature of an in vivo is measured using an InGaSb infrared thermometer, and measured temperature data is transferred to the cloud using the EEBIMP algorithm. So, in this work, the rectal temperature is obtained by measuring the temperatures of cow using InGaSb infrared thermometer. By considering this aspect, the developed work can be extended to livestock application in order to exhibit excellent and competitive performances, which will undoubtedly show better results in the near future.

6. OVERVIEW OF THE RESULTS

More sensitive detector technologies are necessary to improve on the current generation of radiation thermometers. Infrared thermometers use photosensitive sensors, such as semiconductor photodiodes, to determine the temperature. A significant element of infrared devices is that the surface temperature of an experiment can be estimated without any contact with the target object. The schematic and layout of this proposed thermometer is as depicted in Figure 4.

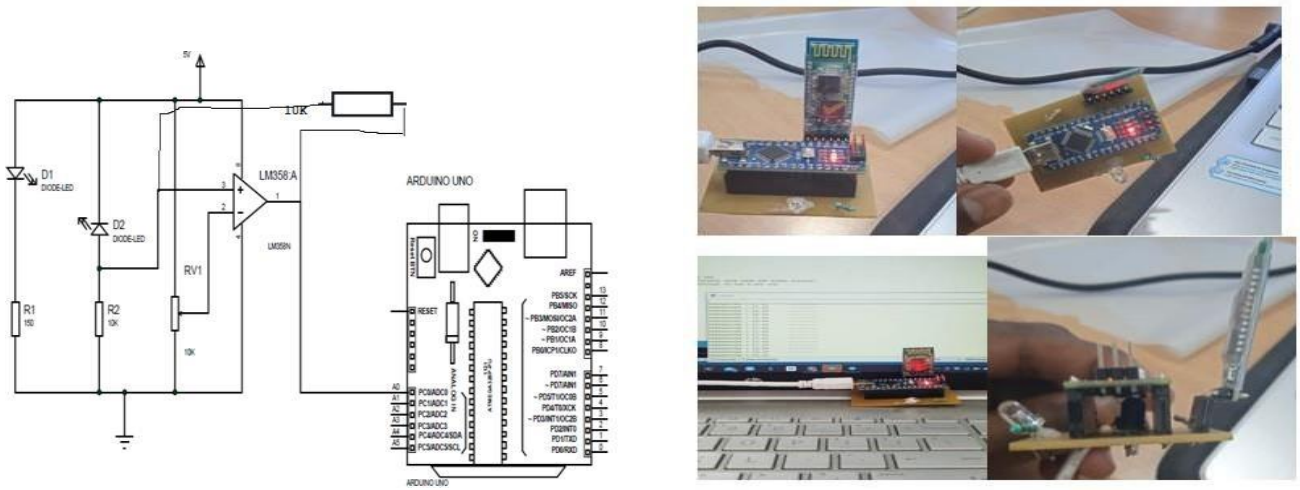
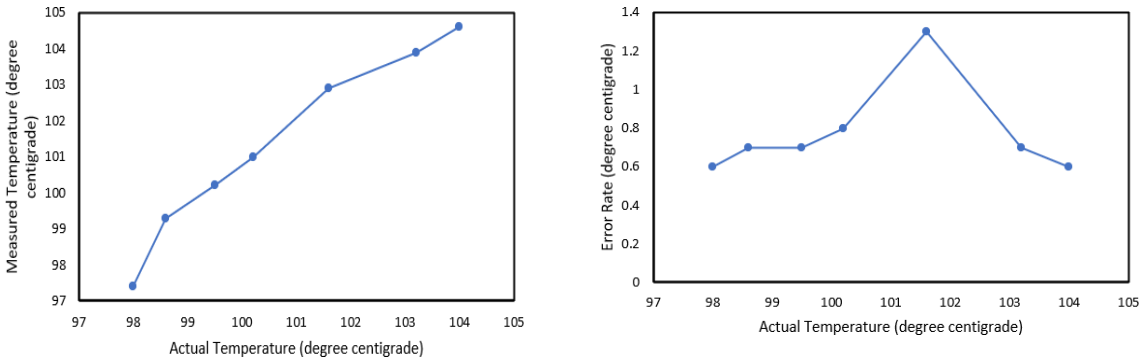


Figure 4: Prototype of the InGaSb Infrared Thermometer



(a) (b)

Figure 5: (a) Comparison of the Measured Temperature (T_{emp}) with Actual Temperature (T_{emp}), (b) Error rate (E_r) of Actual Temperature (T_{emp}) with MeasuredTemperature(T_{emp})

The XY dimensions specify the actual and measured temperature values in degrees Celsius as depicted Figure 5.(a) The error rate (Er) is computed between theactual and measured temperatures as depicted in Figure 5.(b) The actual and measured T_{emp}values are illustrated with the incident angle as shown in Figure 6. The prototype has been experimented for 10 volunteers (5 Male, 5 female) in comparison with the traditional Fluke and Ivoomi thermometer available in themarket. From the measured results, it is revealed that the IR thermometry (Proposed Device) has achieved 95% efficiency compared to the available devices. The comparative measurement of 10 volunteers is tabulated in Table 3. Graphical representation of Figure.6 shows the Comparison of Temperature (T_{emp}) (Measured and Actual T_{emp}) to Incident angle measured for 10 volunteers

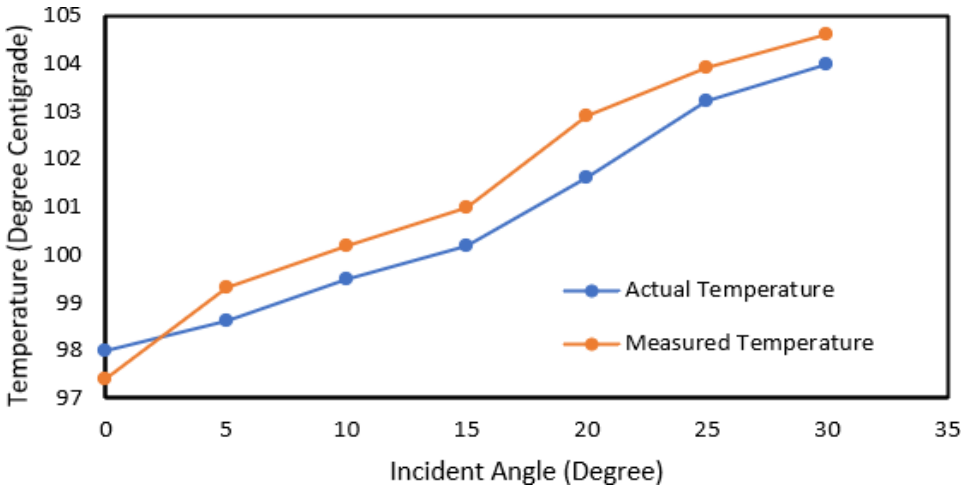
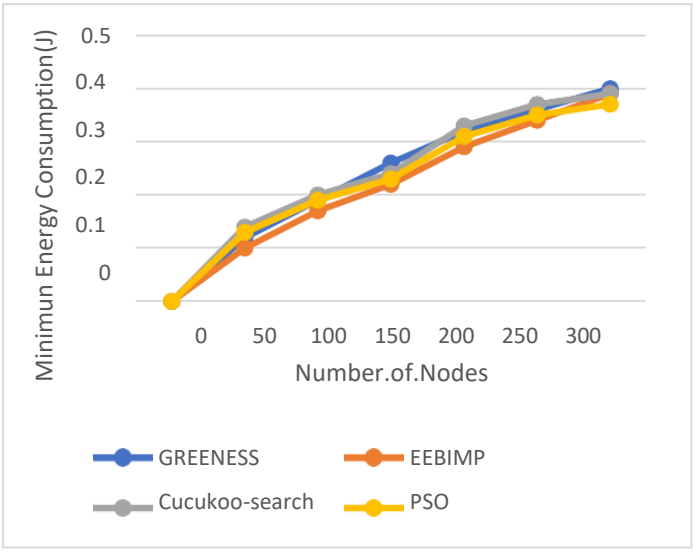


Figure 6: Comparison of Temperature (T_{emp}) (Measured and Actual T_{emp}) to Incident angle measured for 10 volunteers

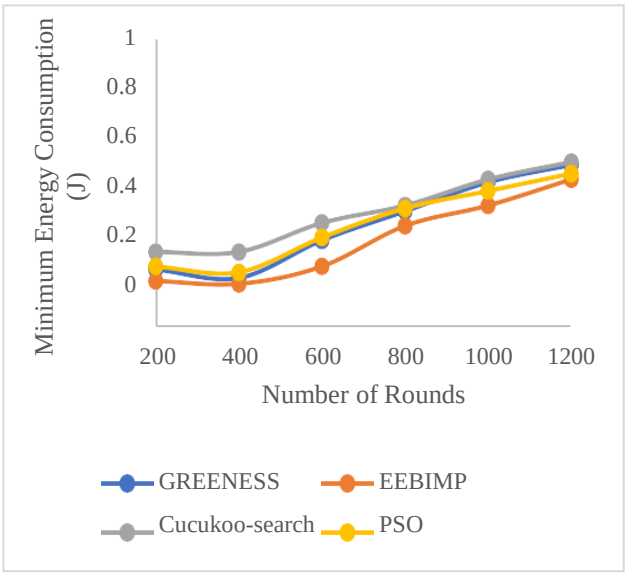
Table 3: Comparative measurement of temperature for 10 volunteers

S.No.	Volunteers	Traditional Measurements	InGaSb Infrared Thermometer
1.	Male 1	98	97.63
2.	Male 2	98.5	98
3.	Male 3	98.2	97.8
4.	Male 4	99	98.1
5.	Male 5	98.3	98
6.	Female 1	98.1	98
7.	Female 2	97	96.8
8.	Female 3	96	96
9.	Female 4	97	97
10.	Female 5	98	97.6

Wireless sensor networks will receive temperature measurement data and forward it to the cloud for storage. An energy-efficient algorithm was used to send the recorded temperature data to the cloud via a wireless sensor network. This work proposed an Energy Efficient Bio-Inspired Mimosa Pudica (EEBIMP) algorithm. EEBIMP for WVSN can reduce the time delay and avoid unnecessary energy consumption.



(a)



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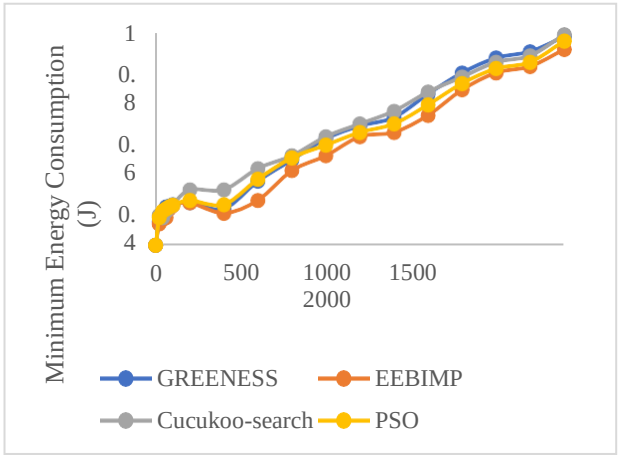

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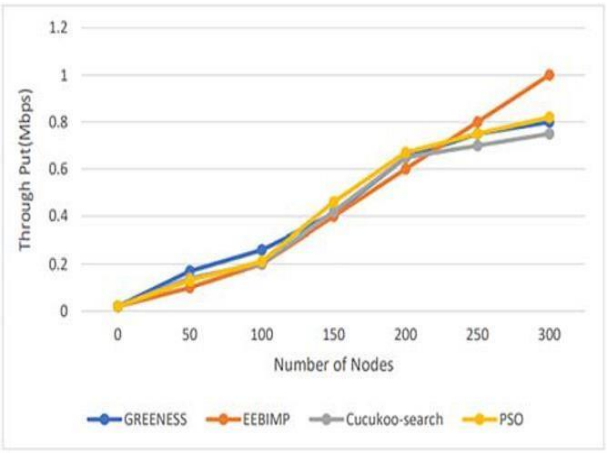


(d)

Figure 7: (a) Energy consumption versus 300 number of nodes **(b)** Minimum energy consumption versus1200 number of rounds **(c)** Minimum energyconsumption versus 2000number of rounds **(d)** Throughput

The temperature of an in vivo is measured using an InGaSb infrared thermometer, and measured temperature data is transferred to the cloud using the EEBIMP algorithm. So, in this work, the rectal temperature results are compared to those obtained by measuring the temperatures of cow. By considering this aspect, the developed work can be extended to veterinary application in order to exhibit excellent and competitive performances, which will undoubtedly show better results in the near future. The Figure 8 shows the snap of measurements taken on cow with designed Infrared Thermometer.

Figure 8: Temperature measurements of cow using Infrared Thermometer

Table 4: Correlation Co-efficient between i) rectal temperature (RT) & Tail Base(TB) ii) rectal temperature (RT) & abdominal area (ADT)

No.of.Days	Correlation Co-efficient(r) for n=75 cows over 30 days period					
	HF.CROSS.COWS(n=25)		RED SINDHI(n=25)		KANGEYAM COWS(n=25)	
	Correlation (r) between RT Vs TB	Correlation (r) between RT Vs ADT	Correlation (r) between RT Vs TB	Correlation (r) between RT Vs ADT	Correlation (r) between RT Vs TB	Correlation (r) between RT Vs ADT
1	0.85	0.76	0.86	0.74	0.82	0.73
2	0.82	0.73	0.84	0.73	0.83	0.72
3	0.81	0.71	0.81	0.72	0.84	0.71
4	0.83	0.72	0.83	0.71	0.85	0.72
5	0.84	0.74	0.84	0.74	0.81	0.74
6	0.85	0.75	0.82	0.72	0.81	0.75
7	0.84	0.76	0.85	0.73	0.84	0.71
8	0.84	0.73	0.83	0.75	0.83	0.71
9	0.83	0.75	0.82	0.71	0.82	0.70
10	0.83	0.74	0.81	0.73	0.81	0.72
11	0.81	0.76	0.82	0.75	0.83	0.73
12	0.82	0.74	0.81	0.74	0.84	0.72
13	0.83	0.75	0.83	0.71	0.85	0.73
14	0.84	0.75	0.84	0.74	0.85	0.72
15	0.81	0.71	0.85	0.75	0.84	0.73
16	0.81	0.72	0.84	0.75	0.83	0.72
17	0.84	0.71	0.82	0.71	0.82	0.73
18	0.84	0.73	0.83	0.72	0.82	0.73
19	0.85	0.74	0.84	0.71	0.81	0.72
20	0.83	0.72	0.85	0.73	0.81	0.74
21	0.81	0.76	0.81	0.74	0.80	0.74
22	0.84	0.75	0.83	0.75	0.80	0.74
23	0.84	0.73	0.84	0.71	0.85	0.73
24	0.83	0.75	0.82	0.73	0.85	0.72
25	0.82	0.76	0.85	0.74	0.84	0.71
26	0.86	0.74	0.83	0.72	0.85	0.74
27	0.85	0.73	0.84	0.74	0.85	0.75
28	0.83	0.74	0.86	0.75	0.86	0.73
29	0.84	0.74	0.84	0.75	0.84	0.75
30	0.86	0.74	0.84	0.75	0.85	0.74

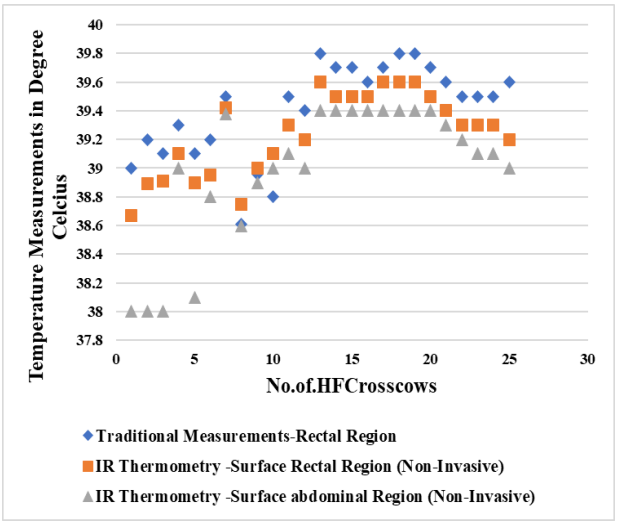
Compared to the existing invasive method with relevant products used for livestock applications, the InGaSb infrared thermometer works well in all its aspects. InGaSb thermometer was used to measure the temperature of cows. The experimental cows were observed daily from July to August (30 days).

Table 4 depicts the correlation co-efficient between i) rectal temperature (RT) & Tail Base (TB) ii) rectal temperature (RT) & abdominal area (ADT). Table 5 depicts the mean and standard deviation of temperatures observed from July to August 2021 (30 days) for n=75 cows. It clearly shows that the rectal temperature was strongly correlated with rectal

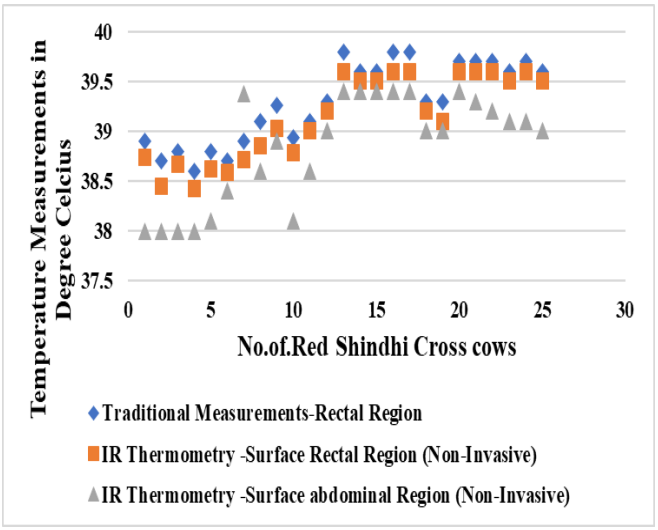
temperature with a correlation ofr = 0.87, $p < 0.01$ and abdominal temperature was closely correlated with rectal temperature with the correlation of r = 0.73, $p < 0.01$, respectively. Figure 9 shows the comparison of temperature measurements from 3 different types of cows

Table.5. Mean and Standard Deviation Calculation

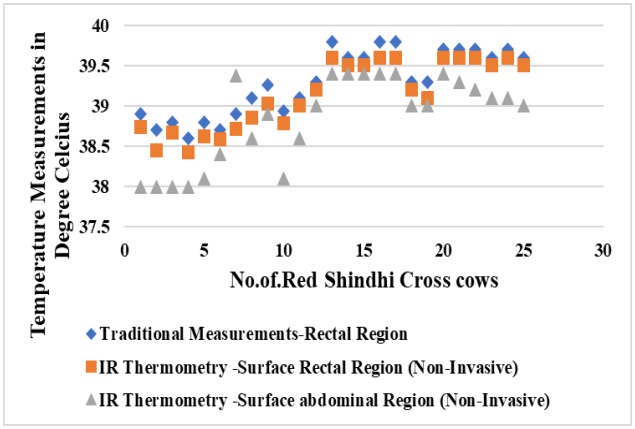
HF cross		**RED Sindhi**		**Kankeyam Cross**	
Mean±SD (RT&TB)	**Mean±SD (RT&ABT)**	**Mean±SD**	**Mean±SD (RT&ABT)**	**Mean±SD**	**Mean±SD (RT&ABT)**
38.66± 0.04	37.12±0.17	38.82±0.08	37.3±0.02	38.83±0.10	36.3±0.04
37.23±0.17	37.06±0.03	38.58±0.12	37.2±0.06	39.04±0.125	36.2±0.05
36.25±0.05	36.1±0.08	38.75±0.06	37.6±0.06	39.05±0.04	36.1±0.05
37.88±0.22	36.9±0.06	38.52±0.08	36.8±0.05	39.2±0.07	36.5±0.03
36.47±0.03	36.2±0.04	38.71±0.09	36.7±0.03	39.01±0.02	36.9±0.04
37.54±0.04	35.1±0.05	38.64±0.05	36.9±0.04	39.07±0.15	36.6±0.03
38.12±0.09	35.4±0.01	38.81±0.09	36.7±0.01	39.46±0.10	37.12±0.17
37.38±0.02	37.6±0.03	38.98±0.12	35.8±0.02	38.68±0.10	37.06±0.03
36.56±0.06	37.3±0.02	39.15±0.12	36.8±0.05	38.98±0.10	36.1±0.08
38.82±0.08	37.2±0.06	38.86±0.08	36.1±0.08	38.95±0.10	36.9±0.06
35.15±0.15	37.6±0.06	39.05±0.05	36.9±0.06	39.4±0.10	36.2±0.04
37.40±0.10	36.8±0.05	39.25±0.05	36.2±0.04	39.3±0.05	35.1±0.05
38.62±0.08	36.7±0.03	39.7±0.01	35.1±0.05	39.7±0.05	35.4±0.01
38.78±0.02	36.9±0.04	39.55±0.05	36.7±0.03	39.6±0.10	37.6±0.03
35.51±0.10	36.7±0.01	39.55±0.05	36.4±0.05	39.6±0.10	36.9±0.04
35.41±0.10	35.8±0.02	39.7±0.01	36.3±0.04	39.55±0.10	36.7±0.01
36.45±0.15	36.8±0.05	39.7±0.01	36.2±0.05	39.65±0.10	35.8±0.02
36.75±0.15	36.7±0.03	39.25±0.05	36.1±0.05	39.7±0.10	36.8±0.05
37.5±0.10	36.4±0.05	39.2±0.01	36.5±0.03	39.7±0.10	36.7±0.03
36.52±0.05	36.3±0.04	39.65±0.05	36.9±0.04	39.6±0.10	36.4±0.05
35.35±0.05	36.2±0.05	39.65±0.05	36.6±0.03	39.5±0.20	36.3±0.04
37.51±0.02	36.8±0.07	39.65±0.05	36.4±0.05	39.4±0.10	36.2±0.05
37.23±0.17	36.5±0.02	39.55±0.01	36.2±0.05	38.68±0.10	36.5±0.02
36.25±0.05	36.4±0.05	38.64±0.03	36.3±0.04	38.98±0.50	36.4±0.05
37.88±0.22	36.3±0.04	38.81±0.02	36.4±0.05	38.95±0.40	36.3±0.04
38.62±0.08	36.7±0.03	39.7±0.01	35.1±0.05	39.7±0.05	35.4±0.01
38.78±0.02	36.9±0.04	39.55±0.05	36.7±0.03	39.6±0.10	37.6±0.03
35.51±0.10	36.7±0.01	39.55±0.05	36.4±0.05	39.6±0.10	36.9±0.04
37.5±0.10	36.4±0.05	39.2±0.01	36.5±0.03	39.7±0.10	36.7±0.03
36.56±0.06	37.3±0.02	39.15±0.12	36.8±0.05	38.98±0.10	36.1±0.08


Temperature Measurements in Degree Celcius
No.of.HFCrosscows
Traditional Measurements-Rectal Region
IR Thermometry -Surface Rectal Region (Non-Invasive)
IR Thermometry -Surface abdominal Region (Non-Invasive)

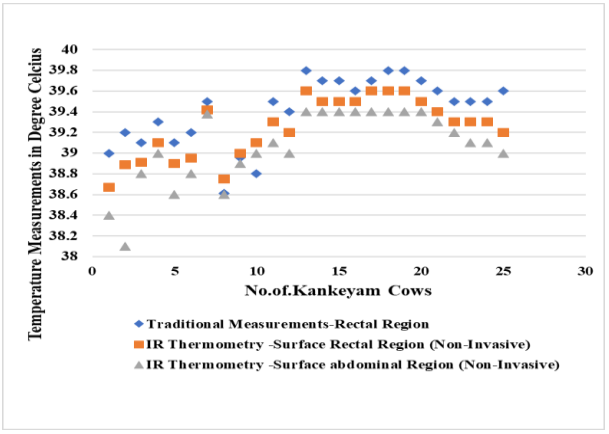
(a)


Temperature Measurements in Degree Celcius
No.of.Red Shindhi Cross cows
Traditional Measurements-Rectal Region
IR Thermometry -Surface Rectal Region (Non-Invasive)
IR Thermometry -Surface abdominal Region (Non-Invasive)

(b)


Temperature Measurements in Degree Celcius
No.of.Red Shindhi Cross cows
Traditional Measurements-Rectal Region
IR Thermometry -Surface Rectal Region (Non-Invasive)
IR Thermometry -Surface abdominal Region (Non-Invasive)

(c)


Temperature Measurements in Degree Celcius
No.of.Kankeyam Cows
Traditional Measurements-Rectal Region
IR Thermometry -Surface Rectal Region (Non-Invasive)
IR Thermometry -Surface abdominal Region (Non-Invasive)

(d)

Figure 9:(a) Temperature comparison between i) Invasive rectal temperature (RT) & tail base (TB) ii) Invasive rectal temperature (RT) & abdominal area (ABT) of Red shindhi Cows, **(b)** Temperature comparison between i) Invasive rectal temperature (RT) & tail base (TB), ii) Invasive rectal temperature (RT) & abdominal area (ABT) of Red shindhi Cows, **(c)**Temperature comparison between i) Invasive rectal temperature(RT) & tail base (TB), ii) Invasive rectal temperature (RT) & abdominal area (ABT) ofRed shindhi Cows, **(d)** Bland Altman plot

So, in this work, the rectal temperature is obtained by measuring the temperatures of cow using InGaSb infrared thermometer. These InGaSb infrared thermometer are highly correlated with traditional digital thermometers in the tail base region. In this work, the results show that an infrared thermometer can be used to estimate the temperature of the cow's core body temperature.

7. ORGANIZATION OF THE THESIS

The structure of this thesis is organized into eight chapters, as follows:The research work is structured into seven chapters and is as follows:

Chapter 1

This chapter 1 explains the important of body temperature measurements andtypes of thermometers.

Chapter 2

This chapter 2 discusses the literature review of earlier methods of temperature measurement in vivo and how the measured temperature values are stored in IOT.

Chapter 3

This chapter 3 discusses an energy-efficient technique was used to send the recorded temperature data to the cloud via a wireless sensor network. A few issues come in front for any such setting like energy inefficiency, throughput unfairness, and, low network capacity. This work proposes a holistic solution named Energy Efficient Bio-Inspired Mimosa Pudica (EEBIMP) algorithm. EEBIMP for WVSN can reduce the time delay and avoidunnecessary energy consumption. EEBIMP algorithm has been compared with one of the most recent notable solutions, like GREENNESS (Green wiReless vidEo sENsor NEtworks uSing out-of-band Signalling), PSO (Particle Swarm Optimization), and Cuckoo Search algorithm.

Chapter 4

Chapter 4 explains the importance of measuring the temperature of cattle. Recent research has examined several methods, for detecting body temperature of cattle in several locations, including the skin surface, vagina, subcutis, and rumen. However, the potential for device loss and the potential for stress induction are the drawbacks to these approaches. In this work, proposed, for the first time, the use of an innovative infrared (IR) photodiode thermometer to detect the temperature of cattle in real-time.

Chapter 5

The chapter 5 analyzes the description of all research work in relation to our priorities and the results obtained. The future work analyzes the possibilities of applyingand expanding the Infrared thermometer in various application areas.

8. CONCLUSION

InGaSb infrared thermometer has been used to monitor the temperature variations in temperature in vivo. Conventional measurement methods are inefficient, slow, and inaccurate. In this work, because of its high thermal conductivity for infrared radiation,a TSFF5210 photodiode based on Indium Gallium Arsenide (InGaSb) material is employed to measure the temperature in vivo. Wireless sensor networks will receive temperature measurement data and forward it to the cloud for storage. An energy-efficient algorithm was used to send the recorded temperature data to the cloud via a wireless sensor network. This work proposed an Energy Efficient Bio-Inspired Mimosa Pudica (EEBIMP) algorithm. EEBIMP for WVSN can reduce the time delay and avoid unnecessary energy consumption. EEBIMP algorithm has been compared with one of the most recent notable solutions, like GREENNESS, PSO (Particle Swarm Optimization), and Cuckoo Search algorithm. The results show that EEBIMP achieved 95% of energy efficiency when compared with other energy efficiency algorithms. The temperature of an in vivo is measured using an InGaSb infrared thermometer, and measured temperature data is transferred to the cloud using the EEBIMP algorithm. So, in this work, the rectal temperature is obtained by measuring the temperatures of cow using InGaSb infrared thermometer. By considering this aspect, the developed work can be extended to this particular livestock application in order to exhibit excellent and competitive performances, which will undoubtedly show better results in the near future. When compared to other traditional sensors, the InGaSb infrared thermometer was developed to achieve better sensitivity and specificity with a minimum wavelength and low power consumption.

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